7 The Demographics and Reproductive Biology of Spotted Seatrout, *Cynoscion nebulosus*, in Six Northwest Florida Estuaries

Douglas A. DeVries, Chad D. Bedee, Christopher L. Palmer, and Stephen A. Bortone

CONTENTS

ABSTRACT

Spotted seatrout were collected from the six westernmost estuarine systems in northwest Florida — Perdido, Pensacola, Choctawhatchee, St. Andrew, St. Joseph, and Apalachicola bays — to determine if and how life history parameters and demographics differed among them. Most specimens were collected by hook and line, with gill nets providing the remainder. Length-frequency data on the recreational fishery were obtained from volunteer anglers and hook-and-line sampling was done by study personnel. Gonadosomatic indices (GSIs) were highest during late April to July; the spawning season varied slightly among the estuaries. Macroscopic maturity stage data indicated that spawning peaked during May and June. Size of females at 50% maturity was 230 mm FL, equating to an age of 1. Males appeared to mature at similar or even smaller sizes. Size distributions from the

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hook-and-line fishery were similar among estuaries. Recruitment occurred at 250 mm FL; modes were 275 to 375 mm FL; and virtually none were > 650 mm FL. St. Joseph and St. Andrew bays had the most truncated distributions. Fish ages 1 and 2 constituted 69 to 89% of the recreational fishery, with few over age 3. Age distributions varied considerably among bays and between years, seasons, and sexes within bays. Estimates of instantaneous total mortality rate (Z) were variable (0.49 to 2.05) and were highest in Perdido Bay and lowest in St. Andrew and Pensacola bays.

INTRODUCTION

Spotted seatrout, speckled trout, or specks (*Cynoscion nebulosus*) have long attracted the attention and interest of the commercial and recreational fishing sectors in Florida. They represent one of the most preferred recreational fish in the state, with many clubs dedicated to their pursuit. Spotted seatrout are often captured in larger numbers by the recreational sector than by the commercial (Mercer, 1984). Since the early 1970s, total Gulf landings have declined significantly, a trend attributed to habitat loss, winter cold kills, and overfishing (Mercer, 1984). Landings in the Florida Panhandle (Escambia to Franklin County) ranged from 69 to171 t (metric tons) during 1981 through 1989 and then dropped to 52 t in 1990 and 29 t in 1991 (Florida Department of Environmental Protection). These large drops can probably be attributed, in part, to the initiation of harvest limits by the Florida Marine Fisheries Commission (MFC) in late 1989, as well as to the previously mentioned causes. In July 1995, a constitutional amendment banning all entangling nets in Florida waters went into effect, virtually eliminating the commercial fisheries for the species.

The spotted seatrout is one of the few economically important species in Florida that is estuarine dependent throughout its life (Tabb, 1966). Several researchers have shown that the species is primarily nonmigratory; adults remain within the same estuary in which they were spawned, although they do show seasonal movements within the estuaries and to nearshore coastal waters (Guest and Gunter, 1958; Moffett, 1961; Iverson and Tabb, 1962; Tabb, 1966; Overstreet, 1983; Music and Pafford, 1984; Baker et al., 1986).

Findings of limited movements, differential growth among estuaries, and some genetic differences prompted some authors to suggest that estuaries may contain distinct subpopulations (Iverson and Tabb, 1962; Weinstein and Yerger, 1976; Baker et al., 1986); however, some electrophoretic studies have found no evidence to support that hypothesis (Paschall, 1986; Ramsey and Wakeman, 1987; King and Pate, 1992). Very recently, examination of restriction site variation in mtDNA yielded further evidence that spotted seatrout are spatially subdivided into discrete subpopulations or stocks (Gold et al., 1999).

Although the genetic evidence is conflicting, because of the well-documented nonmigratory nature of spotted seatrout, each estuary's population is subjected to different exploitation rates and environmental factors, which almost certainly impact demographics, reproduction, and recruitment. Sound management of this very important species requires current data on these parameters from as many estuaries as possible. To date, there is no published information on the life history parameters of spotted seatrout, and little or no detailed information on characteristics of the recreational fishery, from any of the five northwest Florida estuaries west of Apalachicola Bay. The species was studied in Apalachicola Bay from 1986 to 1988 (Murphy and Taylor, 1994) and from 1957 to 1958 (Klima and Tabb, 1959).

The overall goal of this study was to collect the life history and demographic information necessary to manage spotted seatrout in Northwest Florida rationally. Specific objectives were to develop estuary-specific information on age and growth, mortality rates, spawning seasonality, age and size at maturity, and age and size composition of the recreational fishery for Apalachicola, St. Joseph, St. Andrew, Choctawhatchee, Pensacola, and Perdido Bay systems, as well as to test the hypothesis that these life history parameters and demographics differed among each of these estuaries. Our findings on all but age and growth, which are presented in Chapter 6, are presented here.

METHODS AND MATERIALS

The study was conducted from May 1994 through August 1996 in the six westernmost estuaries in northwest Florida; from west to east, these are Perdido, Pensacola, Choctawhatchee, St. Andrew, St. Joseph, and Apalachicola bays (Figure 7.1). Perdido Bay was sampled from May 1995 to July 1996; Pensacola Bay from May 1994 to April 1995; Choctawhatchee Bay from May 1995 to June 1996; St. Andrew Bay from May 1994 to November 1995; St. Joseph Bay from April 1995 to August 1996; and Apalachicola Bay from April 1995 to August 1996.

Spotted seatrout were collected from St. Andrew and Pensacola bays using hook and line and gill nets (79-mm stretch mesh), although after June 1994, only the former gear was used in St. Andrew Bay. Biological data were also obtained from commercially harvested fish (91-mm stretch mesh) in Pensacola Bay and from fish entered in monthly fishing tournaments in St. Andrew Bay. These tournaments provided most of our larger, older specimens. Fish were collected using hook and line from St. Joseph and Apalachicola bays and hook and line and experimental gill nets from Choctawhatchee and Perdido bays. Many specimens from Apalachicola Bay were also obtained from a fishing camp, Bay City Lodge, where a number of guides specialize in fishing for spotted seatrout much of the year.

Upon capture, specimens were immediately put on ice. At the laboratory, and within 24 h of capture, the fish were measured to the nearest millimeter for fork length (FL), total length, and standard length, they were weighed to the nearest gram, their sexes were noted (except in very immature specimens), and their gonads were removed and weighed to the nearest 0.1 g. Maturity stage of gonads was determined visually, using criteria from Overstreet (1983) and Brown-Peterson et al. (1988). A squash preparation from the ovary of every fifth female processed was examined with a dissecting microscope at 6 to 50× as a quality control check for the visual staging. Gonadosomatic index (GSI) was calculated as gonad weight/total weight × 100. Otolith processing and aging methods are given in Chapter 6.

The official birth date for all fish was January 1. Fish collected after April 1 (April corresponds to the onset of spawning and annulus formation) but before January 1 of the next year were placed in an age class corresponding to the number of observed annuli. Fish caught between January 1 and April 1 were placed in an age class corresponding to the number of observed annuli plus one, with the exception of the few fish that laid a new annulus during that period; these were placed in an age class corresponding to the observed number of annuli.

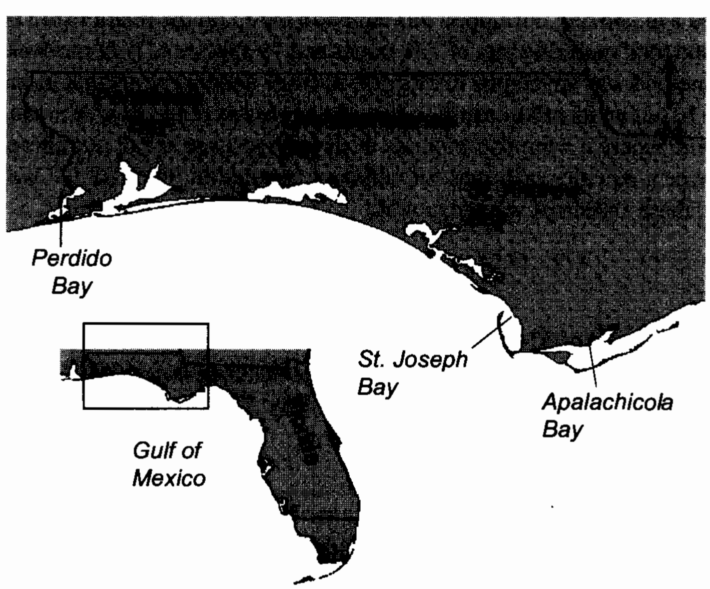

FIGURE 7.1 Northwest Florida estuarine systems where spotted seatrout were sampled.

Length frequency data on the recreational fishery were obtained from hook-and-line sampling by laboratory personnel and from volunteer recreational anglers. In most cases, lengths from hook-and-line-caught specimens collected for biological samples were included in the length frequency data sets. Length data from fishing tournaments were not included, as those catches were not representative of the fishery. Volunteers recorded the length of each spotted seatrout landed, including those released, using a measuring board with waterproof paper attached to it. The angler would lay the fish on the board and punch a hole in the paper at the middle margin of the caudal fin. When the sheet of paper was returned to project personnel, the data could be retrieved by measuring the distance to each hole. Anglers also recorded date, location, and number of fish caught on the waterproof paper. Each piece of paper had room for nine different trips.

Age composition of the recreational catch was estimated using a combination of two methods. For biological samples that were also valid length-frequency samples, we used the actual age. For the volunteer-caught fish that had not been aged, we converted length data to age data using age–length keys generated from aging data from the same bay, year, season (March to August and September to February), sex, and 50-mm size interval. For the few cases for which there were length data but no matching age data, we used the most appropriate age data available, such as those from the closest size interval or from the previous year or the nearest estuary. Sex was assigned to these unsexed length data using sex ratios generated from the biological samples collected in the same bay, year, season (March to August and September to February), sex, and 50-mm size interval. All references to length are in fork length.

Four different methods were used to estimate instantaneous total mortality rates (Z): standard least squares (LS) catch curve analysis (Ricker, 1975), the maximum likelihood (ML) method of Robson and Chapman (1961), and the methods of Hoenig (1983) and Royce (1972). For the least squares and maximum likelihood methods, we used the total, sexes-combined, age composition data (ln transformed for the least squares) from each estuary. For St. Andrew and Apalachicola bays, it was not obvious which was the first fully recruited age class, so two estimates were made, one with the youngest modal age class and one without it. Estimates were also made using data sets that excluded any of the older age classes with fewer than five fish for all but Apalachicola Bay, where the oldest age class had ten individuals. For the LS method, residuals were examined for homogeneity of variance (t test) and normality (Shapiro-Wilk statistic and normal probability plot). LS estimates of Z between estuaries were compared by examining the interaction terms in the analysis of variance (ANOVA).

Hoenig's (1983) method uses the predictive regression equation: $\ln(Z) = 1.44 - 0.982 \ln(t_{max})$, where t_{max} = maximum observed age. Hoenig developed this equation based on the relationship between maximum observed age and total mortality rate of 134 stocks and 79 species of fish, mollusks, and cetaceans. Royce's (1972) method was developed to estimate average annual instantaneous natural mortality (M) and was also based on its relationship to maximum observed age. Royce's equation basically equates to $M = 4.6/n$, where n = number of years from youngest age at full recruitment to maximum observed age. Royce's equation assumes an unfished population; because we were sampling exploited populations, these estimates were Z, not M.

RESULTS

Biological data were obtained from a total of 3742 spotted seatrout (2306 females and 1436 males) — 224 from Perdido Bay, 602 from Pensacola Bay, 367 from Choctawhatchee Bay, 1206 from St. Andrew Bay, 562 from St. Joseph Bay, and 781 from Apalachicola Bay. The overall size distributions by sex of the biological samples are shown in Figure 7.2.

REPRODUCTION

Plots of GSIs for both sexes by estuary showed elevated values, indicating spawning activity, from early April until mid-September across the region (Figures 7.3 and 7.4). Reproductive activity was

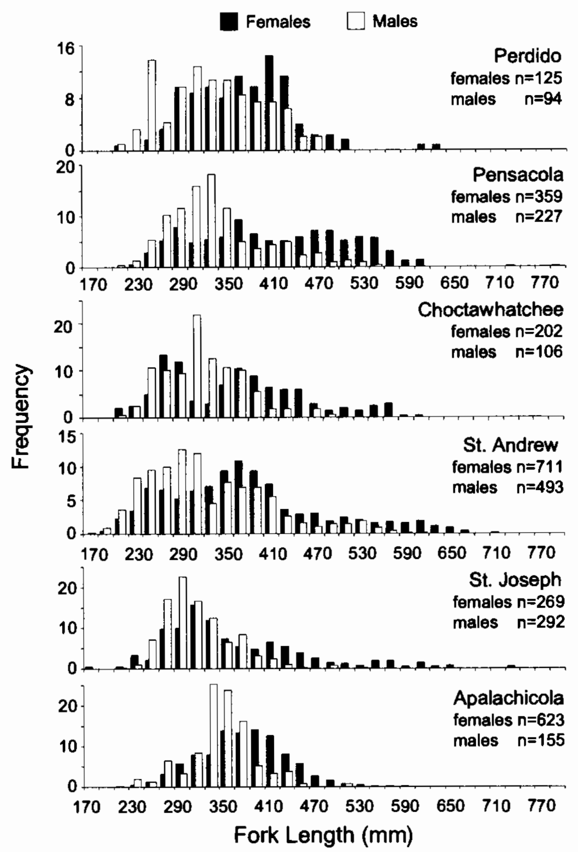

FIGURE 7.2 Total length frequency distributions by sex and estuary of spotted seatrout used in reproductive analyses and to generate age-length keys.

highest from late April through July. There was some evidence that the spawning season varied slightly among the estuaries. GSI data from St. Andrew and Apalachicola bays for both sexes appeared slightly bimodal, with peaks in May and July in the former and early May and August in the latter (Figures 7.3 and 7.4). GSIs for females in Pensacola Bay showed one mode in late July to early August, but this pattern was not evident for males from Pensacola. In St. Joseph Bay, GSIs for both sexes appeared to decline slowly throughout the spawning season, although there was never an obvious mode. Spawning in that estuary, and possibly in Choctawhatchee Bay, seemed to end a few weeks earlier than in the other Panhandle estuaries. No obvious modes were visible in the GSI data of either sex from Perdido and Choctawhatchee bays, nor from males from Pensacola, possibly because of small sample sizes.

Macroscopic maturity stage data from females supported the GSI results; i.e., between 59 and 85% of females were gravid (late developing) during April through August, with some evidence of activity in September as well, when 26% were gravid (Figure 7.5). The proportions were highest during May and June (85%), suggesting that spawning peaked then, with no real indication of a bimodal season. A plot of the monthly proportion of gravid females by estuary did suggest a secondary spawning peak in August in St. Andrew Bay, but this was not apparent in any of the other systems (Figure 7.6). Proportions of spent females peaked in August and September at 15 and 17%, respectively.

Using maturity stage 3 (early vitellogenesis or early developing) as our criterion for sexual maturity, logistic regression of the proportions of mature and immature fish indicated that 50% of female spotted seatrout in Choctawhatchee, St. Andrew, and St. Joseph bays are mature by the time they attain 230 mm (Figure 7.7). Size at maturity is probably similar in the other three bays. The

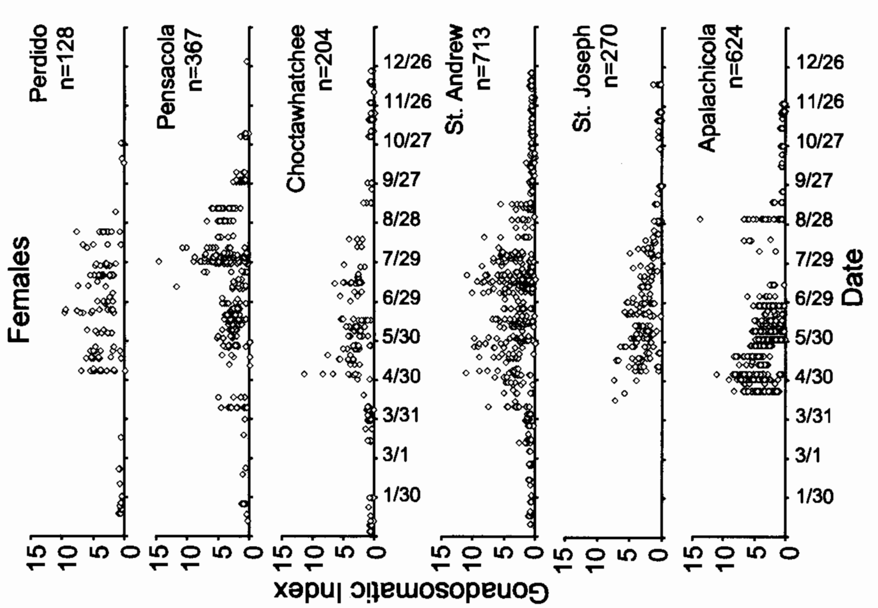

FIGURE 7.3 Plot of raw gonadosomatic indices data by day of the year and estuary for female spotted seatrout.

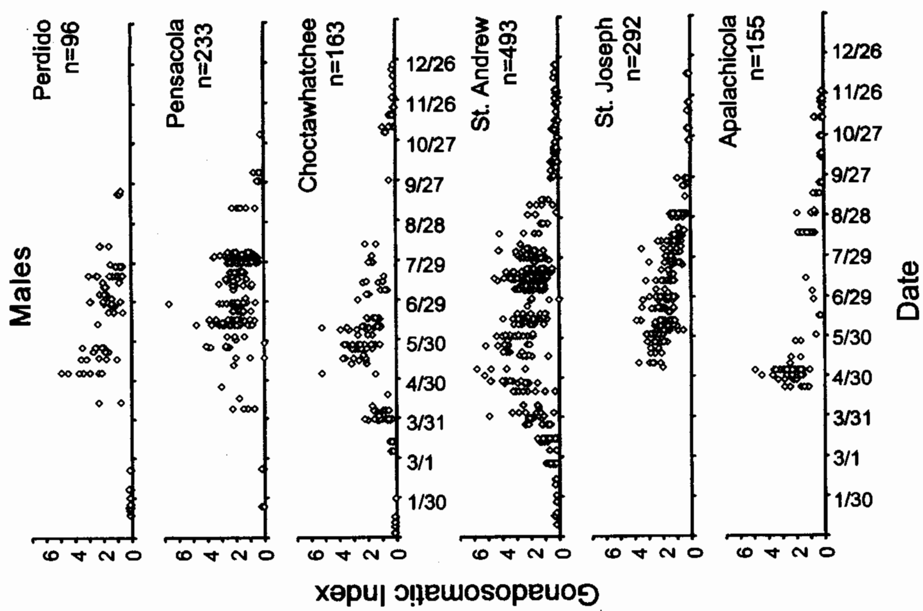

FIGURE 7.4 Plot of raw gonadosomatic indices data by day of the year and estuary for male spotted seatrout.

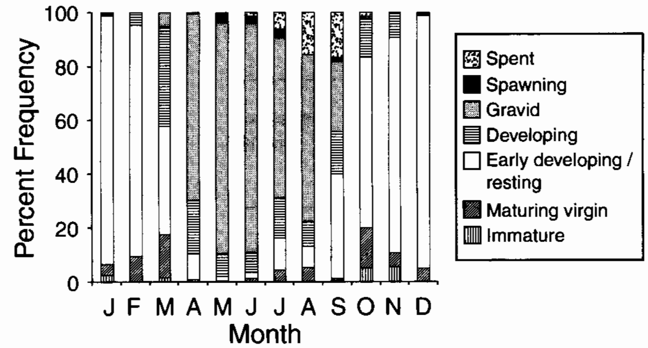

FIGURE 7.5 Monthly frequency distributions of macroscopic maturity stages of all female spotted seatrout collected from the six estuarine systems in northwest Florida.

predicted proportion of mature females in Pensacola Bay at 250 mm FL, the smallest interval with data, was 66%, so most certainly at 230 mm at least 50% were mature. All but one female from Perdido Bay and all females from Apalachicola Bay were mature; the former had three fish below the 270-mm interval, two at 250-mm, and one at 210 mm. In the latter there were three below the 250-mm interval, two at 230 mm, and one at 210 mm. At 50% maturity, a size of 230 mm equates to an age of no more than 1 year, and in some cases this would be age 0. By 290 mm, the proportion of mature females ranged from 0.78 to 1.00, and at this size almost all fish are still age 0 or 1.

Males appeared to mature at similar or even smaller sizes than females. Predicted size intervals at which 50% of the males were mature, based on logistic regression, were between 250 and 270 mm for Choctawhatchee Bay, < 190 mm for St. Andrew Bay, and < 230 mm for St. Joseph Bay (Figure 7.8). All males collected in Perdido, Pensacola, and Apalachicola bays were mature, and the smallest size interval in each bay was 230, 210, and 230 mm, respectively. Except for Choctawhatchee Bay, males of these sizes would all be age 0 or 1. In Choctawhatchee Bay, roughly 5% of males between 250 and 270 mm were age 2, while the rest were age 0 or 1.

Size Composition

The overall size distributions from the hook-and-line fishery were similar among the six estuaries, with recruitment occurring at about 250 mm and modes somewhere between 275 and 375 mm (Figure 7.9). The fishery was dominated by fish below 450 mm; they constituted between 87.6 (St. Andrew) and 96.5% (Pensacola) of samples. Few fish were above 550 mm (0 to 3.8%) and virtually none were above 650 mm. There were, however, some small differences among the bays. St. Joseph Bay, and St. Andrew to a lesser extent, had the most skewed distributions and were dominated by smaller fish — 250 to 350 mm. Fish > 350 mm constituted only 26 to 27% of samples from those two estuaries, compared to 42 to 45% in the other four bays. Pensacola and Choctawhatchee bays had the largest proportion of large fish, with 5.2 and 5.3% between 500 and 600 mm, compared to 0.6 to 2.4% in the other four estuaries (Figure 7.9). When the size distributions were examined by sex, there were no dramatic differences; although modal size of males was less than that of females in all but Perdido and Choctawhatchee bays, females dominated the upper ends in each system (Figure 7.9).

The size distributions of seatrout caught by project personnel and by volunteer anglers in St. Andrew Bay for use in characterizing the fishery were very similar; collection of size data by volunteers was most successful by far in that bay. In both data sets the distribution was unimodal, with a mode between 250 and 350 mm, and few fish < 200 mm or > 450 mm were caught (although volunteers

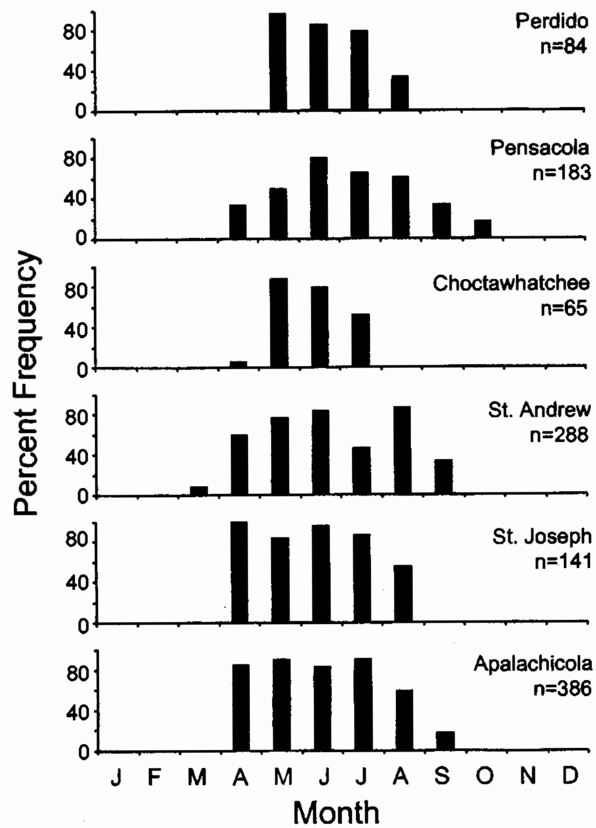

FIGURE 7.6 Monthly proportions of gravid (stage 5) female spotted seatrout by estuary.

did catch a higher proportion of those < 200 mm) (Figure 7.10). Because the distributions were so similar, we felt it was valid to pool these data for the size and age composition analysis. In Apalachicola Bay, where we had much less cooperation from recreational anglers, the size distributions of project- and volunteer-caught fish were also similar, although not quite as similar as in St. Andrew Bay. The overall size range was the same but the mode was much more defined in St. Andrew Bay (Figure 7.10); however, we still felt the distributions were sufficiently similar to allow pooling of the data.

Age Composition

Fish ages 1 and 2 dominated and few over age 3 were taken in the recreational hook-and-line spotted seatrout fishery in the Florida Panhandle, although the age distribution varied considerably among bays and between seasons and sexes within bays (Figure 7.11). One- and two-year olds made up 88.5, 70.0, 70.9, 80.2, 69.2, and 69.3% of the catch in Perdido, Pensacola, Choctawhatchee, St. Andrew, St. Joseph, and Apalachicola bays, respectively. If age-0 fish are included, these proportions increase to 91.6, 72.8, 82.3, 87.3, 95.0, and 85.8%, respectively; when 3-year-olds are added, these numbers rise to 98.5, 86.7, 95.8, 93.8, 97.0, and 96.3%, respectively.

Within estuaries, age structure shifted seasonally and annually to varying degrees. In each estuary, young-of-the-year were caught almost exclusively during the fall-to-winter (September to February) period, as can clearly be seen in the seasonal plots from St. Andrew Bay (Figure 7.12). This pattern was most apparent in St. Joseph Bay, where 67.9% were young-of-the-year during these months. In Perdido Bay the dominant age class shifted from age 1 in summer 1995 to age 2 in summer 1996. Age-2 fish dominated in Pensacola Bay both years that it was sampled, but the proportion of age-1 fish dropped from about 35% during March to August 1994 (the period of greatest effort) to about 10% the following March-to-August period.

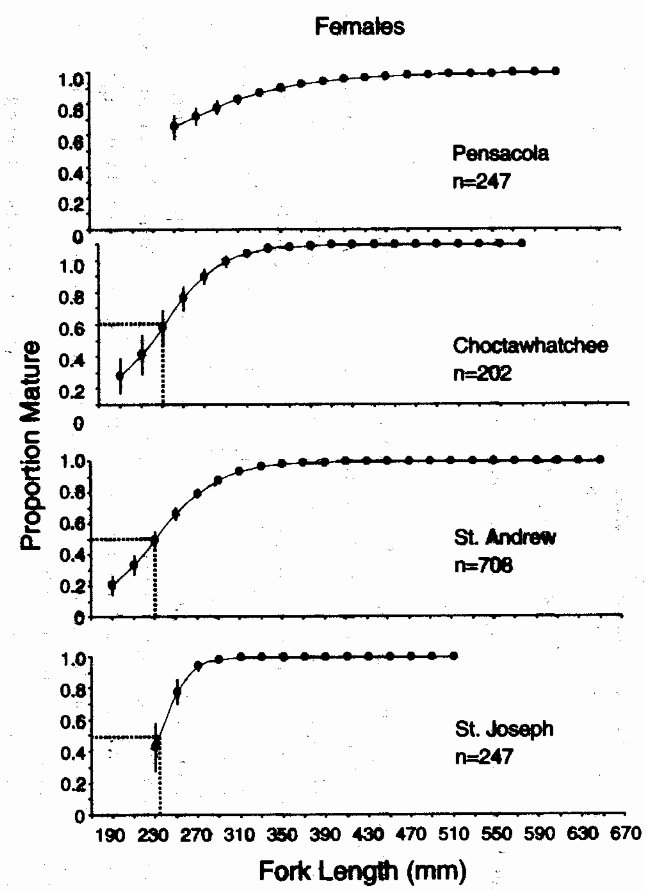

FIGURE 7.7 Predicted proportions (and standard error) of mature female spotted seatrout at size by estuary. Stage 3 or early developing fish were considered mature. The dotted line indicates the predicted size at which 50% would be mature.

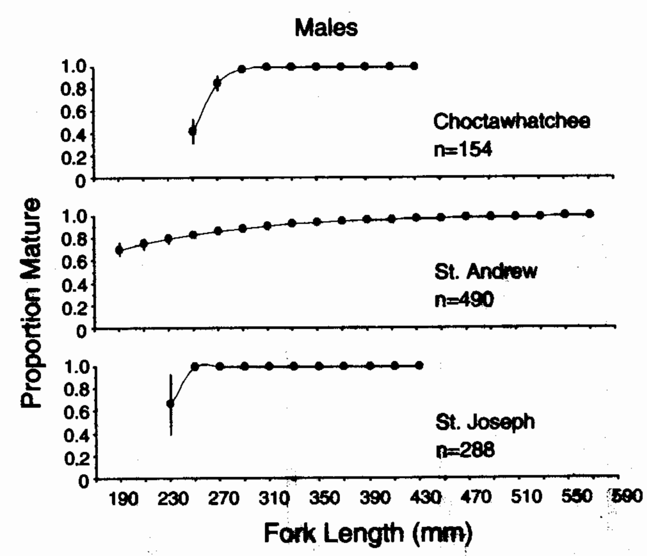

FIGURE 7.8 Predicted proportions (and standard error) of mature male spotted seatrout at size by estuary. Stage 3 or early developing fish were considered mature.

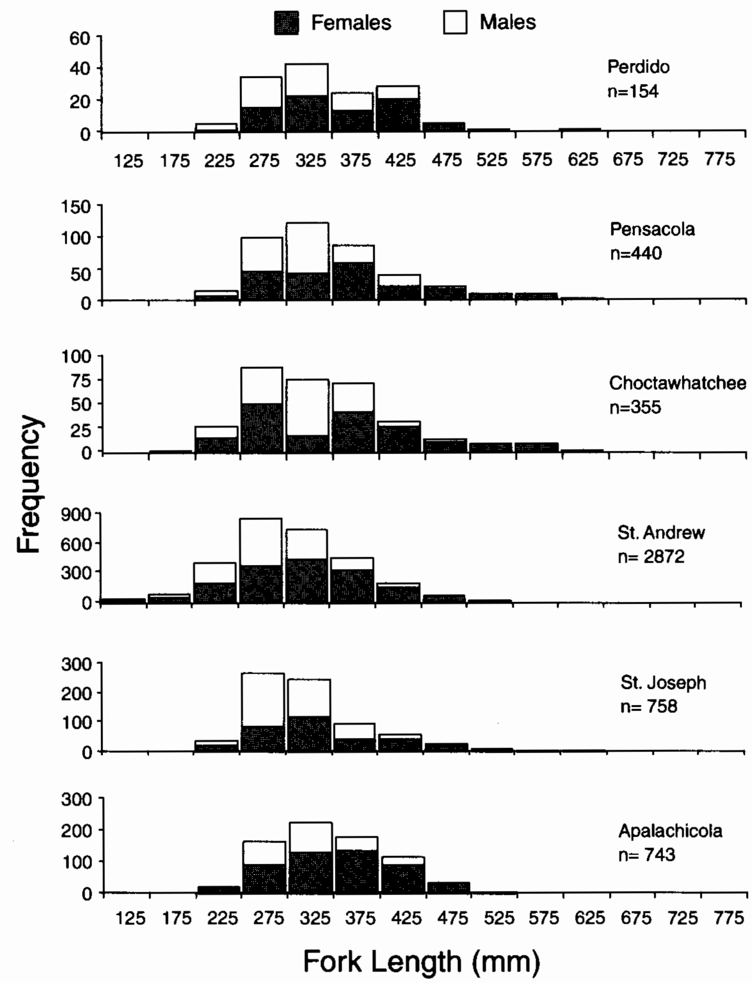

FIGURE 7.9 Overall size distributions of hook-and-line-caught spotted seatrout by estuary.

In Choctawhatchee Bay, age-1 and age-2 fish completely dominated the fishery in spring to summer 1994 (91.3%), but one year later, age-2 and age-3 fish composed 79.7%, with only about 12% constuting age 1 fish. Age-1 and age-2 seatrout dominated the St. Andrew Bay fishery both years it was sampled, but during March to August 1994, they were about equally abundant; 1 year later, age-2 fish were only about half as abundant as age-1 fish (Figure 7.12). During March to August 1994, the catch in St. Joseph Bay was almost all age-1 fish (83.3%), with age-2 fish constituting < 10%; a year later age-1 fish again predominated (60%), but age-2 spotted seatrout were much more abundant, constituting 30% of the catch. In Apalachicola Bay during March to August 1995, the mode was age 3, while during March to August 1996, most fish (81.4%) were age 1 and only 8.7% were age 3. During both fall-to-winter periods, ages 0 to 2 were all important in the fishery, while age-3 fish contributed only about 5%.

Age structure between sexes was quite variable among estuaries and ages but showed no consistent pattern (Figure 7.11). Among fish age 3 and above, the proportion of males in the catch was slightly more than twice that of females ($\overline{x} = 2.1$, SE = 0.13) at each age in Pensacola and St. Andrew bays, while in Apalachicola Bay, there were 3.2 and 6.6 times as many males as females at ages 3

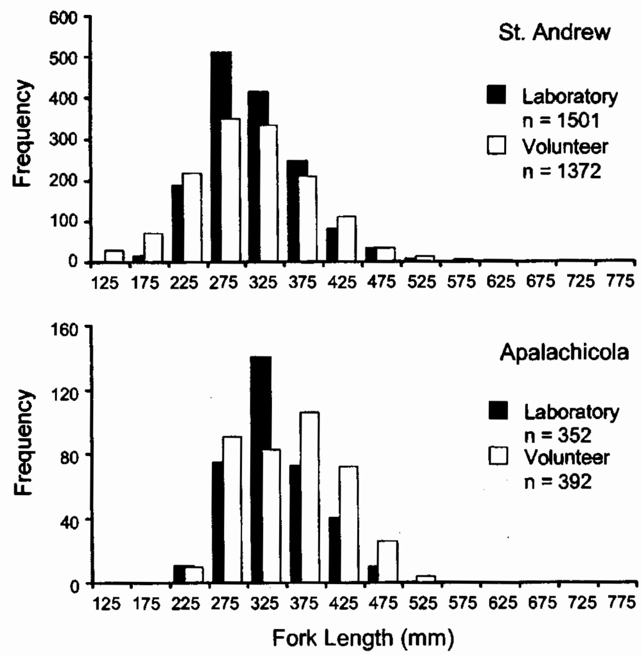

FIGURE 7.10 Total size distributions of all spotted seatrout collected in St. Andrew and Apalachicola bays by lab personnel and volunteer anglers for characterizing size and age composition of the recreational fishery.

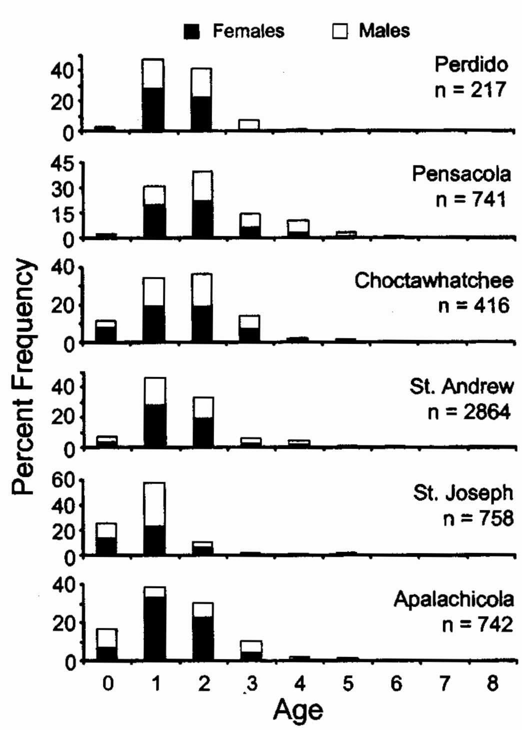

FIGURE 7.11 Total age distributions of spotted seatrout caught by hook and line, by estuary.

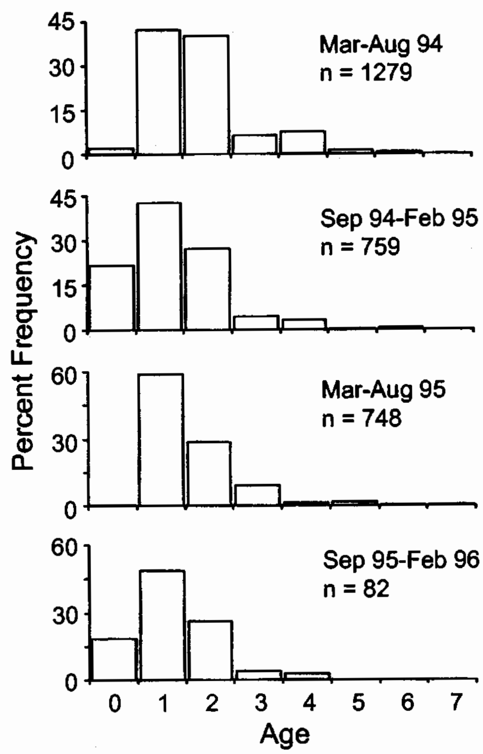

FIGURE 7.12 Seasonal age distributions of spotted seatrout caught by hook and line in St. Andrew Bay.

and 4 and only males at age 5. In contrast, in St. Joseph Bay, females at ages 3, 4, and 5 were 2.3, 11, and 2.2 times as abundant as males, respectively. In Perdido and Choctawhatchee bays, the pattern was mixed, with males exceeding females at age 3 and then females exceeding or about equal to males above that age, although sample sizes were quite small for these two systems.

Total Mortality Rates

Estimates of instantaneous total mortality rate (Z) were quite variable, ranging from a low of 0.49 to a high of 2.05 (Table 7.1). The Robson-Chapman ML and LS catch curve estimates, which ranged from 0.80 to 2.05, tended to be higher and more similar to each other than the estimates determined using the Hoenig and Royce methods, which ranged from 0.55 to 1.15 and were also similar to each other. Both ML and LS estimates of Z for sexes combined were highest for Perdido Bay (1.740 and 1.558, respectively); the lowest ML estimate came from St. Andrew Bay (0.866), while Pensacola Bay yielded the lowest (0.821) LS estimate (Table 7.1; Figure 7.13).

Of the LS estimates for sexes combined, the only statistically significant differences were between Perdido and Pensacola bays ($p = 0.019$) and between Perdido and St. Andrew bays ($p = 0.037$) (Table 7.2). Among the ML estimates for sexes combined, 95% confidence limits did not overlap between 1) Perdido and Pensacola, Choctawhatchee, St. Andrew, and Apalachicola bays; 2) St. Andrew and Choctawhatchee, St. Joseph, and Apalachicola bays; and 3) Pensacola and Choctawhatchee, St. Joseph, and Apalachicola bays (Table 7.1). Although not true statistical tests, these nonoverlapping confidence intervals certainly suggest differences in mortality rates of spotted seatrout among these estuaries. Confidence intervals of the LS estimates were much larger (96 to 565%, $\overline{x} = 367\%$) than those of the ML estimates.

Estimates of total mortality by sex showed no consistent pattern. Robson-Chapman ML estimates of Z ranged from 0.676 to 2.054 for males and from 0.683 to 1.299 for females. Males had a higher mortality rate than females in Perdido and St. Joseph bays, while females had higher rates in

TABLE 7.1
Estimates of Instantaneous Total Mortality Rate (Z) Derived from Four Methods for Spotted Seatrout from Perdido (PDO), Pensacola (PEN), Choctawhatchee (CHW), St. Andrew (SAB), St. Joseph (SJB), and Apalachicola (APL) Bays in Northwest Florida

				Robson-Chapman		Least Squares Catch Curve		Hoenig							
								Females		Males		Royce			
Bay	Ages	Sex	n	Z	95% CL	Z	95% CL	Z	Max Age	Z	Max Age	Z	Yrs3	Z	Yrs3
PDO	2–5	F+M	109	1.740	1.418–2.218	1.558	0.678–2.438	0.869	5	0.727	6	1.15	4	0.92	5
PDO	2–3[1]	F+M	106	2.023	1.640–2.654										
PDO	1–2[1]	F	109	0.683	0.497–0.911										
PDO	2–3[1]	M	56	1.179	0.963–1.454										
PEN	2–6	F+M	494	0.918	0.835–1.007	1.075	0.556–1.593	0.727	6	0.624	7	0.92	5	0.77	6
PEN	2–5[1]	F+M	491	0.936	0.852–1.028	0.821	0.287–1.356								
PEN	2–5[1]	F	237	1.128	0.984–1.296	1.046	0.570–1.521								
PEN	2–5[1]	M	254	0.809	0.710–0.920	0.840	0.078–1.252								
CHW	2–6	F+M	227	1.189	1.034–1.372	1.231	0.899–1.563								
CHW	2–5[1]	F+M	226	1.214	1.055–1.404	1.146	0.461–1.830	0.727	6	0.869	5	0.92	5	1.15	4
CHW	2–4[1]	F	226	1.299	1.065–1.606	1.205	0.122–2.532								
CHW	2–3[1]	M	104	0.676	0.443–0.980										
SAB	1–7[2]	F+M	2660	0.866	0.831–0.901	0.978	0.816–1.141	0.548	8	0.488	9	0.58	8	0.51	9
SAB	1–6[1,2]	F+M	2656	0.872	0.838–0.907	0.937	0.708–1.167								
SAB	1–6[1,2]	F	1472	0.971	0.920–1.026	1.041	0.740–1.341								
SAB	1–6[1,2]	M	1184	0.774	0.729–0.822	0.845	0.637–1.052								
SAB	2–6[1]	F+M	1315	1.168	1.102–1.239	0.995	0.627–1.363								
SJB	1–6	F+M	562	1.367	1.249–1.500	1.050	0.552–1.548	0.548	8	0.869	5	0.58	8	0.92	5
SJB	1–5[1]	F+M	561	1.385	1.266–1.520	0.943	0.124–1.762								
SJB	1–5[1]	F	249	1.104	0.966–1.264	0.795	0.147–1.443								
SJB	1–3[1]	M	307	2.054	1.808–2.381	1.989	1.674–2.304								
APL	2–5[1]	F+M	332	1.198	1.067–1.349	1.089	0.514–1.664	0.869	5	0.869	5	1.15	4	1.15	4
APL	1–3	F	442	1.074	0.972–1.187	1.031	-3.754–5.818								
APL	2–5[1]	M	130	0.807	0.670–0.965	0.663	0.010–1.316								
APL	1–5[1,2]	F+M	620	0.834	0.768–0.906	T0.931	0.550–1.311								

Note: Bays are listed in geographic order from west to east.

[1] Samples which included only age classes with at least 5 fish. [2] Samples which included an aditional younger age class because identification of the first fully recruited age class was not obvious [3] Number of years used to calculate Z, i.e. number of years from first fully recruited age to maximum age.

the other four bays (Figure 7.13). In estuaries with enough age classes to calculate them, LS estimates showed the same patterns. The difference between sexes was greatest in St. Joseph Bay, where Z for females was 1.104 vs. 2.054 for males; however, the 95% confidence intervals did not overlap in any of the estuaries. Estimates of Z calculated using the methods of Hoenig and Royce also showed no consistent differences between sexes, and the patterns they did show differed from those from ML and LS methods. Male mortality rates exceeded those for females in Choctawhatchee and St. Joseph bays, while the rates in Apalachicola were equal (Table 7.1).

DISCUSSION

REPRODUCTION

GSI data indicating that spotted seatrout spawned from April through August were consistent with previous studies. In the northeastern Gulf of Mexico, Klima and Tabb (1959) reported that spawning occurred from late April through September in Apalachee and Apalachicola bays, with a possible peak in late May or early June; Moffett (1961) found spawning from May through September in Cedar Key and Fort Myers, with a peak during summer. Brown-Peterson et al. (in review) documented an April-to-August season, peaking in June, in Apalachicola Bay and a March-through-September season, with no obvious peak, in Charlotte Harbor in southwest Florida.

Based on GSIs and visual and histological staging, Overstreet (1983) reported that seatrout in Mississippi spawn from May through August. More recently, Brown-Peterson and Warren (2000) reported a mid-April to mid-September season in that state, based on GSI data. Studies in south Texas (Brown-Peterson et al., 1988) and east Texas (Maceina et al., 1987) found significantly higher GSIs among spotted seatrout from April to September and concluded that spawning occurred during those months. The bimodal pattern in spawning activity found in St. Andrew and Pensacola bays has been documented in several other studies along the Atlantic and Gulf coasts (Stewart, 1961; Hein and Shepard, 1979; Brown-Peterson and Thomas, 1988; Brown-Peterson et al., 1988).

The significance of the differences in temporal GSI distributions (Figures 7.3 and 7.4) among estuaries is unclear. Although differences in spawning activity among these estuaries are likely, the

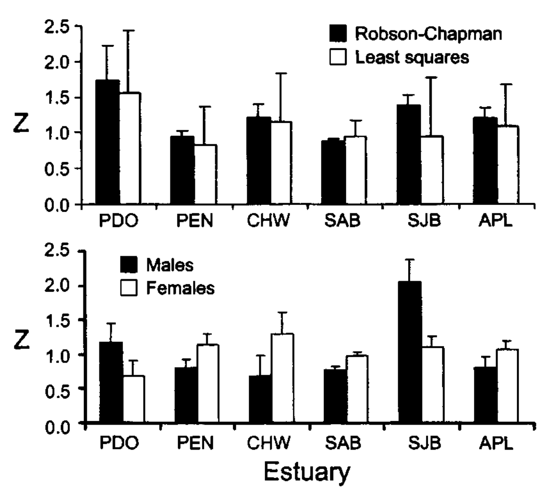

FIGURE 7.13 Estimates of total instantaneous mortality (Z) of spotted seatrout by estuary. Top panel: estimates of Z calculated using the Robson-Chapman and least squares methods. Bottom panel: Robson-Chapman estimates of Z by sex. Error bars = 95% C.L., PDO = Perdido, PEN = Pensacola, CHW = Choctawhatchee, SAB = St. Andrew, SJB = St. Joseph, and APL = Apalachicola.

TABLE 7.2
Results of F Tests for Differences in Total Instantaneous Mortality Rate Z Derived from Catch Curves (equality of slopes in the ln percent frequency on age relationship) Between Spotted Seatrout from Different Pairs of Bays

	Ages		Bay				
Bay	**Incl.**		**APL**	**SJB**	**SAB**	**CHW**	**PEN**
PDO	2–5	F	3.68	2.62	10.2	2.53	9.47
		Pr>F	0.128	0.166	0.019	0.187	0.037
PEN	2–5	F	2.15	0.11	0.49	2.58	
		Pr>F	0.217	0.749	0.508	0.184	
CHW	2–5	F	0.07	0.31	1.38		
		Pr>F	0.799	0.604	0.284		
SAB	1–6	F	0.82	0.00			
		Pr>F	0.401	0.982			
SJB	1–5	F	0.16				
		Pr>F	0.702				
APL	2–5						

Notes: APL = Apalachicola, SJB = St. Joseph, SAB = St. Andrew, CHW = Choctawhatchee, PDO = Perdido, and PEN = Pensacola. Values in bold indicate pairs with statistically different slopes.

data are confounded by unequal sampling effort and sample size as well as the logistic necessity of sampling different bays in different years. Brown-Peterson and Warren (2000) noted that the rapid increase in GSI during the spring (indicating the beginning of spawning activity) occurred in Mississippi about one month earlier in 1999 than in 1998.

Time of day at which the fish were collected may also have confounded the findings. For example, for logistic reasons, sampling of St. Joseph Bay occurred primarily from early morning to early afternoon. Because this species apparently spawns in the evening (Brown-Peterson et al., 1988), it is not surprising that no spawning (hydrated) females were collected there and, therefore, that fish had lower GSIs than in almost all the other estuaries. Differences in the size distribution of the samples among estuaries at a given time are still another possible confounding factor; i.e., most of the fish from an estuary in a given month were so small that many were immature, GSI estimates could be affected greatly. Spotted seatrout tend to school by size, especially at smaller sizes; these smaller fish seem to be easier to catch by hook and line, so they might be overrepresented at some times in some places.

Size-at-maturity estimates from this study are consistent with those of Klima and Tabb (1959) but somewhat lower than those of Brown-Peterson et al. (in review) — the only other data available from the region. Size at 50% maturity was about 230 mm FL for females in three of the six estuaries, and data from the other three suggest similar sizes. At 290 to 310 mm FL, virtually all females were mature. Klima and Tabb (1959) did not define a "mature" fish but stated that all females from Apalachicola and Apalachee bays were mature by the time they were 27 cm SL (314 mm FL). Brown-Peterson et al. (in review) estimated that 50% of female spotted seatrout from Apalachicola Bay matured by 300 mm TL (298 mm FL), which is about 70 mm larger than our estimate; their smallest was 285 mm TL. This difference may reflect differences in our definitions of maturity or in methodology or possibly temporal variation, as our study occurred 8 to 10 years after theirs.

Our data suggest that males mature at slightly smaller sizes than females; Klima and Tabb (1959) found that all males were mature by about 25 cm SL (292 mm FL). Overstreet (1983) found gravid (stage 5) females as small as 189 mm SL (226 mm FL) and males down to 201 mm SL (239 mm FL) in Mississippi. In a recent study in Mississippi, Brown-Peterson and Warren (2000) estimated size at 50% maturity of females to be 230 mm SL (270 mm FL), with the smallest mature female at 225 mm SL (265 mm FL); however, only 3% of the 432 females collected were immature, so their estimate may have been biased. In South Carolina, Wenner et al. (1990) reported that 83.3% of six males < 238 mm TL (237 mm FL) were mature, as were all males above that size. Among females 273 to 284 mm TL (271 to 282 mm FL) they found 63.6% were mature, as were 100% of those larger than that size. The smallest ripe male and female collected in Florida Bay by Rutherford et al. (1982) were 237 mm SL (278 mm FL) and 230 mm SL (270 mm FL), respectively.

Using age–length keys, we estimated that close to 100% of male and female spotted seatrout mature by age 1. Klima and Tabb (1959) reported that males may mature "by the end of their first year of life" (late age zeros?), females may mature by the "end of the second year of life" (late age 1?), and all fish spawn by age 3 (age 2?). Wenner et al. (1990) found that 409 of 410 age-1 males and 97.1% of 930 age-1 females in South Carolina were mature. Brown-Peterson and Warren (2000) reported that 80% of age-1 females from Mississippi were mature, and all 117 of the males they collected were mature, with the smallest being 201 mm SL at age 1.

Size Composition

The skewed size distributions with a dominance of smaller fish that we observed in St. Joseph and St. Andrew bays may reflect the impact of higher exploitation rates in those two systems, although this is certainly speculation at this point. The truncation of the size and age structure is a typical response of fish populations to fishing. Based on our observations, the exploitation rate appears to be much higher in St. Joseph and St. Andrew bays than in Apalachicola Bay, where the proportion of larger fish was much greater. This difference in exploitation rates is probably related to the fact that the former two bays are much closer to a populated area (Panama City), are aesthetically much more attractive, and, because of water clarity, are much easier for a person unfamiliar with the bay to find productive fishing sites. A note of caution is warranted for the Apalachicola data. Many of the more successful catches there were dominated by fish in a rather narrow size range, and certain sites seemed to produce fish of certain sizes, so the choice of fishing sites could definitely affect the size composition data. In addition, many of the sites fished were learned about from guides, who obviously would want to avoid areas where smaller trout tended to occur. The broader size structure seen in Pensacola and Choctawhatchee bays suggests that the exploitation rates in those two systems were lower than in the other four, although this is just speculation since we did not estimate this parameter. One other weakness with the overall size distribution data is that they are affected by the temporal distribution of the samples, which, if not distributed proportionately to the temporal distribution of effort in the fishery, can introduce biases.

Surprisingly, the size composition of seatrout collected with hook and line in Apalachee and Apalachicola bays in 1957 and 1958 (Klima and Tabb, 1959) was very close to what was observed almost 40 years later in most of the estuaries in this study; their modal size was about 320 mm FL and the range was 230 to 450 mm FL. Similarly, the size distribution of fish collected for a tagging study in Apalachicola Bay in 1958 and 1959, primarily by hook and line, ranged from roughly 200 to 500 mm FL with a mode around 350 to 375 mm FL (Moffett, 1961). The size distribution of spotted seatrout caught recreationally in Everglades National Park from 1978 to 1980 was also quite similar to that found in northwest Florida, ranging from about 260 to 540 mm FL with a mode around 350 mm (Rutherford et al., 1982: Figure 2). That the size distributions of spotted seatrout from 35 to 40 years ago are so similar to the ones found in this study during 1994 to 1996 suggests that the species is capable of sustaining a considerable amount of fishing mortality, given that a noticeable truncation in the size structure — with the possible exception of St. Joseph and St. Andrew bays — has apparently not occurred.

The collection of size structure data from volunteer anglers was quite successful, especially in St. Andrew Bay, as evidenced by the similarity between those data and data collected by study personnel and the fact that volunteers basically doubled the sample sizes for at least two estuaries. This method of collecting valuable size structure data was extremely cost effective and yielded apparently unbiased data of considerable value for stock assessment. Another benefit of this method is that it provided information that could not be obtained by dockside sampling about numbers and size structure of fish outside the size limits.

Age Composition

The variation in overall age structure among the six estuaries in northwest Florida further confirms the hypothesis that the nonmigratory nature of this species will tend to produce populations with unique demographics in each estuary because of varying environmental factors and exploitation rates. Given that only two age classes (ones and twos) constituted 69 to 89% of the total recreational catch in all six systems, and assuming larval recruitment varies spatially and temporally, one would predict that these unique demographics are quite dynamic. This prediction is confirmed by the annual variability in age structure seen within each estuary. Murphy and Taylor (1994) found significant differences in the age structure between seatrout from Apalachicola Bay and Indian River Lagoon, Florida, which the authors said suggested that the populations were responding independently to local fishing pressures. Because the age composition values from this study were based on all spotted seatrout caught, including those released, they provide an estimate of the age structure of the population, not just of the legal catch.

In contrast, other studies that have sampled only the retained catch had a 305-mm (12-in.) size limit in effect. Klima and Tabb (1959) reported that age-3 and age-4 spotted seatrout dominated the commercial hook-and-line catches in Apalachee and Apalachicola bays in the late 1950s. In the Everglades National Park, age-3 and age-4 fish also dominated the recreational catch, constituting 45 and 29%, respectively (Rutherford et al., 1982). They noted that anglers frequently caught small, young fish below the 305-mm (12-in.) size limit and released them. In spite of a 305-mm (12-in.) limit, 72 to 77% of the spotted seatrout landed by South Carolina anglers during 1986 to 1988 were age 1 and 94 to 97% were under age 3 (Wenner et al., 1990).

The recruitment of large young-of-the-year during fall and winter was quite evident in the seasonal age distribution data from each estuary (Figure 7.12). This phenomenon underscores the importance of sampling throughout the year to get a true idea of the age structure in a spotted seatrout fishery.

Total Mortality Rates

The large range and significant differences in estimates of Z found among six northwest Florida estuaries support the hypothesis that different exploitation rates and environmental factors in each estuary can result in differences in demographics and population parameters of this nonmigratory species, even within geographically close systems at similar latitudes.

The LS estimate of Z for males in Apalachicola Bay (0.66) from this study was considerably less than the 1.63 that Murphy and Taylor (1994) estimated from fish collected there in 1986 to early 1988. Their estimate was based on ages 1 to 4, while ours included ages 2 to 5. It seems more likely that much of this difference reflects sampling differences — Murphy and Taylor (1994) included fish caught by haul seine, as well as hook and line, in their estimate — because it is unlikely that mortality rates decreased that much in less than 10 years. Our overall range in ML and LS estimates of Z of 0.80 to 2.05 for sexes combined was similar to results from other investigations in the Gulf: Everglades National Park, Z = 1.31 and 1.43 (Rutherford et al, 1982), and Bastrop Bayou, Texas, Z = 1.13 to 1.61, based on a tagging study (Baker et al., 1986). Murphy and Taylor's (1994) estimates from Charlotte Harbor, Florida (1.24 for females and 0.65 for males), were quite similar to some of the estimates from this study.

Although we do think that there are real differences in mortality rates of spotted seatrout among estuaries in northwest Florida, it is important to remember the basic assumptions of these estimation procedures: that all fully recruited age classes are equally vulnerable to the sampling gear; that survival is constant across ages; and that recruitment is constant. It is almost certain that none of these assumptions is completely met with spotted seatrout. In this study, sample size varied widely (106 to 2660) among estuaries; it is likely that the estimates from those with the smaller sample sizes (Perdido, Choctawhatchee, and possibly Apalachicola) may not be accurate. Also, hook-and-line sampling is subject to considerable variability from factors such as differences in angler skill and knowledge of the water body. The fact that this species tends to school or at least aggregate by size, as well as the fact that bait preferences vary with size, can also complicate sampling and bias results. Larger, older fish tend to be more solitary and wary and are probably underrepresented in the collections; this would result in overestimates of mortality.

It is somewhat puzzling that females had a higher mortality rate than males in Pensacola, Choctawhatchee, St. Andrew, and Apalachicola bays, while males had a higher rate in Perdido and St. Joseph bays. Because of small sample size, the Perdido Bay estimates may be inaccurate, but the St. Joseph Bay estimates, which were highly different from each other, were based on fairly large numbers (females = 249; males = 307). Intuitively, one thinks that this difference must reflect a real difference in the fisheries among estuaries, since it is very unlikely that natural mortality rate patterns would differ that much. The higher total mortality rate of females in four of the estuaries could reflect that the faster-growing females are being recruited to the fishery at a younger age and thereby are being exposed to increased fishing mortality. Murphy and Taylor (1994) found higher mortality rates for females than males in Charlotte Harbor and Indian River, Florida. In contrast, Rutherford et al. (1982) reported lower mortality rates for females than males in Florida Bay.

CONCLUSIONS

The use of life history parameters of spotted seatrout as an indicator of environmental health among estuaries, or within an estuary over time, has merit; however, some caveats must be considered with this method. Reproductive parameters in particular, such as GSI, annual or batch fecundity, spawning frequency, and fertilization rates, may provide some evidence of differences or changes in environmental quality among or within estuaries, although it is important to consider the possibility of latitudinal variation (Brown-Peterson and Thomas, 1988; Conover and Present, 1990). Size at maturity has been demonstrated to decline as a result of fishing, so it would be of less utility unless effort was constant. Natural mortality rates would be much less useful. Difficult to estimate accurately in a fished population, these rates can also be affected by such factors as recruitment variation, which is common among teleost fishes, population variation of their predators and prey, and possibly genetic differences (which could also confound interpretation of reproductive differences).

Focusing on fish below the size of recruitment to the fishery would greatly reduce, if not eliminate, effects related to fishing, but it would not help with other confounding factors. Using some other abundant, widely distributed, strictly estuarine, and, most importantly, unfished (even as bycatch) species of teleosts would be a better alternative. However, this would still not solve most of the problems associated with natural mortality rates or, even reproductive parameters if there are genetic differences among estuaries. In the southeastern U.S., some possible candidates might be found among the blenniids (blennies), gobiids (gobies), cyprinodontids (killifish), or batrachoidids (toadfish). A few other suggestions which would improve an interestuarine study of this type include 1) to sample all estuaries during the same years, to eliminate confounding from annual variation; 2) to expend equal amounts of effort and collect similar sample sizes in each system; 3) to be aware of diel effects on GSI, fecundity, and spawning frequency data; and 4) to consider possible effects related to salinity, distance from inlets, and other environmental and hydrological factors when designing the sampling plan and analyzing the results.

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